Published online: 2021-02-01

Facial Protection to Prevent Facial Trauma and Allow for Optimal Protection after Facial Fracture Repair

Roderick Kim, DDS, MD[1] Tom Shokri, MD[2] Weitao Wang, MD[3] Yadranko Ducic, MD, FRCS(C), FACS[4]

[1] Department of Oral and Maxillofacial Surgery, John Peter Smith Health Network, Fort Worth, Texas
[2] Department of Otolaryngology, Pennsylvania State University, Hershey, Pennsylvania
[3] Department of Otolaryngology, University of Rochester Medical Center, Rochester, New York
[4] Department of Facial Plastics, Otolaryngology and Facial Plastic Surgery Associates, Fort Worth, Texas

Address for correspondence Roderick Kim, DDS, MD, Department of Oral and Maxillofacial Surgery, John Peter Smith Health Network, 1625 St. Louis Avenue, Fort Worth, TX 76104 (e-mail: kim0do@uw.edu).

Facial Plast Surg 2021;37:781–789.

Abstract

Facial skeletal fractures continue to affect humankind, and many methods to alleviate and prevent the injuries outright have been sought after. Prevention is desired, but the implementation and general compliance may contribute to missed opportunities to decrease the burden of facial skeletal trauma. In this article, we explore the preventative as well as postoperative options for the protection of the facial skeleton.

Keywords
- facial trauma
- maxillofacial trauma
- facial protection
- CMF trauma
- postoperative protection

The most frequent facial skeletal fracture includes the nasal bone, zygomaticomaxillary complex (ZMC), and the mandible.[1–3] Fracture etiology includes interpersonal violence, motored vehicle collision (MVC), sports, and falls.[1–5] It is postulated that the fracture pattern and thus the function of the facial bone, based on the buttresses (►**Fig. 1A**,**B**, ►**Table 1**), is to protect the soft tissue within the craniomaxillofacial (CMF) complex. These soft tissue include critical structures such as the brain, great vessels, and nerves, as well as the globe. Buttresses are categorized broadly as the transverse and vertical, and each buttress is listed and illustrated in ►**Fig. 1** and ►**Table 1**.

To lessen the effects of trauma and to prevent facial fractures, and thus the soft tissue injuries and functional harm associated with them, facial protection has evolved throughout the years. These protective measures were developed by support from sports communities and dental community, as well the armed forces. Furthermore, injury patterns and the collateral damages have also evolved from the low-velocity trauma and trench warfare of the World War to the high-velocity trauma associated with MVC and the modern warfare. Therefore, the developments in facial protection have followed suit. Ideally, the personal protective equipment has improved the extent of these injuries and yielded ideas to prevent the injury altogether. However, this goal has not been met yet.

In this article, we describe the available preventative options for facial protection, as well as postoperative considerations to optimize the repair, and preview some future concepts and options for facial skeletal trauma prevention.

Preventative Options

Maxillofacial trauma confers long-term physical and psychosocial sequelae and represents a substantial economic burden on the health care system.[6–10] Consequently, the utilization of protective measures is of paramount importance, particularly when individuals may be subject to high socioeconomic or occupational risk or MVC, participate in competitive contact sports, or routinely participate in combat.

published online February 1, 2021

Issue Theme Skeletal Facial Plastic Surgery; Guest Editor: Yadranko Ducic, MD, FRCS(C), FACS

Thieme Medical Publishers, Inc., 333 Seventh Avenue, 18th Floor, New York, NY 10001, USA

DOI https://doi.org/10.1055/s-0041-1723006.
ISSN 0736-6825.

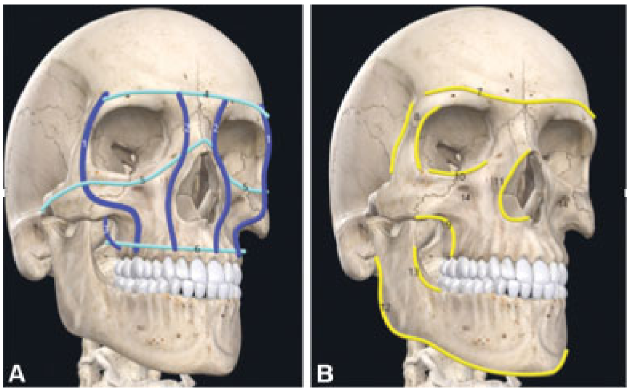

Fig. 1 (**A**,**B**) Outline of the facial buttresses (Reproduced with permission of Wang L, Lee TS, Wang W et al. Surgical management of panfacial fractures. Facial Plast Surg 2019;35(6):565–577.)

Social Factors and Substance Use

While describing the preventative options of facial trauma, it is important to also consider the factors contributing to the situation when the facial trauma occurred. Substance use is a well-known cause for increased risk of trauma, specifically within the head and neck region. Goulart et al demonstrated an increased susceptibility to CMF injury in illicit substance users when compared with trauma patients with negative substance use history.[11] Therefore, facial trauma also has been termed a *recurrent disease* for patients with a history of polysubstance abuse. Substance abuse leads to an increased risk of assault or interpersonal violence, leading to recurrent injuries. Additionally, studies have shown a correlation of alcohol and illicit recreational drug use with the severity of maxillofacial injury.[11–13] Although these patients are at high risk of recurrent and severe maxillofacial injuries, intervention and prevention may be possible. These patients have demonstrated receptivity toward programs reducing violence and stress, suggesting a role for psychosocial strategies such as counseling. Integration of counseling as well as other socioeconomic interventions into patients' global treatment plans should, therefore, be prioritized to mitigate future risk of traumatic CMF injury and the associated morbidity.[11–13]

Occupational Risk

Occupational trauma has been well documented as a common etiology for CMF trauma and directly related to varying vocations with higher risk exposure, such as farm and forest workers, construction workers, and manufacturing workers.[14,15] Although the data regarding occupational CMF injury are limited, work-related injury has been identified as a substantial cause of decreased productivity and increased disability annuity.[16–18] Data regarding the specific anatomical subunit within the CMF skeleton vary.[14,15,19,20] However, head injuries have demonstrated the highest morbidity with an associated increase in disability claims.[16]

The majority of occupational CMF injuries, secondary to impact-related head injuries, are particularly common within the construction industry.[17,18] Additional mechanisms including falls and machinery-related injuries are also reported within the occupation in the literature.[19–21] Therefore, it is understandable that the utilization of a protective helmet, or hard-hat, in addition to personal protective equipment for the eyes and face, is required by the United States Department of Labor and Occupational Safety and Health Administration (OSHA). However, the reported morbidity of head injuries, in conjunction with the high rate of midface and skull base fractures as high as 80% in some studies,[19–21] suggest that current protective equipment is inadequate. Certain occupations, primarily those involving construction and machinery, should therefore consider employing even more stringent safety regulations to mitigate the potential risk of injury to workers, loss of productivity, and the accompanying economic burden of disability.[21] Additionally, consideration should be given to the modification of current conventional industrial helmets to include face shields with midface coverage given the reported high incidence of CMF trauma. However, to further understand the causes, severity, and temporal distribution of CMF injuries, further studies stratifying the demographics, level of training and experience, mechanism of trauma, and protective equipment utilized need to be conducted.

In the CMF region, orbital trauma also represents a significant proportion of occupational injury and therefore requires a special consideration. According to the Centers for Disease Control and Prevention (CDC), approximately 2,000 individuals in the United States experience an occupational eye injury every day.[22] Eye injuries represent up to 12% of work-related disability claims among carpenters and 11% of all injuries among construction workers.[23–25] Welders have demonstrated a particular propensity for orbital trauma, with one study indicating that 21% of all eye injury claims were reported in this profession[26] and are associated with a fourfold increased risk in ocular injury compared with other comparable occupation.[27] Similar to construction CMF trauma literature, there is a paucity of data relating to the specific circumstances or mechanism of welding-related eye injuries. However, the welding process itself exposes individuals to sources of mechanical, thermal, radiant, and chemical energy, all of which carry the potential for injury.

In addition to welding, occupations with exposure to powered tools including carpentry, mechanics, and construction carry similar risks for orbital trauma secondary to particulate matter. Considering the prevention and protection of orbital

Table 1 Facial buttresses

Vertical buttress	Transverse buttress
Zygomaticomaxillary, nasomaxillary, posterior mandibular, pterygomaxillary, nasoethmoidal	Upper transverse facial (includes orbital roof), middle transverse facial (includes orbital floor), lower transverse facial (includes the palate), upper transverse mandibular and lower transverse mandibular

trauma, the majority of injuries may be prevented if appropriate eye protection is employed, as studies have shown that despite workplace availability, approximately half of occupational-related eye injuries occur due to noncompliance with protective eyewear.[28] Prevention strategies may include well documented and distributed eye safety policy, protective eyewear, vision screenings, and frequent spot-checks to ensure policy compliance and use of appropriate workplace precautions. A detailed review of occupational protocols is beyond the scope of this article. Interested readers are directed to relevant references for further details.[29–32]

Motor Vehicle Collisions: The Utility of Restraining Devices

Motor vehicle accidents represent one of the leading causes of facial trauma.[33–37] Due to the significant morbidity associated with this mechanism of injury, much research and development have been achieved by the industry as well as the government departments. One of the most critical developments in safety devices includes the airbags and restraint devices. These devices have been developed to mitigate the risk of life-altering injury and are responsible for countless lives saved. Seatbelts, in particular, have decreased the resultant impact of motor vehicle collisions on the facial skeleton, thus decreasing the incidence of CMF fractures.[36–40] While airbags use alone has not statistically correlated with a change in the incidence of CMF injuries, utilization of both airbags and seat belts has shown an improvement in the reduction of severe head and chest trauma.[39–41] Simoni et al[36] reported that the greatest benefit of these safety devices in the CMF region appeared to be in the prevention of ZMC fractures. However, it is important to stress that incorrect use of airbag may cause resultant injury; potential injury patterns are outlined in ►**Fig. 2A–C**.[36,37,42]

These data also highlight the importance of utilization of both restraint devices and airbags in mitigating the extent of CMF trauma in the setting of MVC, particularly those with frontal impact accidents. Special consideration should be placed within the pediatric population, as restraint type and quality have a significant bearing on the extent of CMF trauma. Head and neck injuries are most common across all pediatric age groups in the setting of MVC. The distinct anatomical features of the pediatric craniofacial skeleton result in distinct injury patterns within this population and must therefore be appropriately accounted for. Improperly restrained or unrestrained pediatric occupants are subject to more severe injuries in contradistinction to their properly restrained counterparts.[43–45] With this in mind, physicians are encouraged to familiarize themselves with the recommendations for appropriate, age-specific, utilization of restraint mechanisms to properly educate guardians as well as facilitate identification of pediatric CMF trauma in the acute settings.[45–48]

Sports-Related Injuries and Personal Protective Equipment

Sports-related maxillofacial injuries result in considerable morbidity and may necessitate surgical intervention leading to extended hospital stays and decreased quality of life. With this in mind, primary prevention of such injuries is essential, particularly in high-risk contact sports. However, there is currently a lack of high level of evidence evaluating the efficacy of protective strategies aimed at mitigating sports-specific facial trauma.

Mouth Guard (Orofacial Protective Devices)

Mouth guards or protective oral appliances are meant to protect from dentoalveolar injury through dissipation of forces between the upper and lower dentition and act as shock absorbers, thus preventing soft tissue trauma as well.[49] The following three main types of appliances have been described within the literature: custom fabricated guards created by dental professionals utilizing patient-specific models, form-fitted "boil-and-bite" guards, and stock guards (meant to be worn immediately without specification).

The American Dental Association recommends utilization of mouth guards in any sport posing risk significant injury to the facial skeleton. Despite these recommendations, mandatory mouth guard policies are not routinely enforced, particularly within the amateur level.[49,50] Studies evaluating the utilization of such protective equipment are limited. However, one such study evaluating the use of mandated mouth guards by the National Collegiate Athletic Association (NCAA) in ice hockey indicated that only 63% of participating athletes complied with this measure.[50] Studies examining the efficacy of mouth guard

Fig. 2 (A–C) Injury patterns during frontal collision in partially, fully, and unrestrained drivers: (**A**) Unbelted driver too close to steering wheel accelerates toward the deploying airbag. (**B**) Belted driver with chest too close to steering wheel, airbag expansion changes—lower part of bag is constrained by chest, causing increase upper bag expansion. This, in turn, may contribute to facial fracture and eye trauma. (**C**) Totally unrestrained driver accelerates toward steering wheel and other rigid parts of vehicle interior. (Reproduced with permission of Roccia et al[36].)

use have shown a substantial reduction in the risk of dental injuries, varying from 43 to 89%.[51–54] Despite their proven efficacy, individuals continue to disregard the use of oral protective appliances citing lack of concern for injury, difficulty with breathing and speech, and general discomfort. Customized mouth guards may provide relief from the majority of these complaints and have shown to provide improved protection when compared with standard devices.[55,56] For example, custom-fitted trilaminate polyvinyl acetate polyethylene mouth guards were associated with 46% reduction in risk of orofacial injuries when compared with nonspecified appliances.[57] Thus, physicians should advocate for and educate patients on the use of oral protective appliances, particularly if participating in high-risk activities.

Face Guards/Helmet/Headgear

The protective capacity of helmets, headgear, and face guards in reducing the risk to the craniofacial skeleton has been demonstrated in multiple sports activities.[58–61] Several governing organizations oversee testing and standardization of this equipment. In the United States, the National Operating Committee on Standards for Athletic Equipment (NOCSAE) has mandated, for example, that all football helmets be equipped with face guards.[62] Furthermore, sports involving projectiles (i.e., baseball, softball, lacrosse) have standards for face guard implementation in helmet design.[63–65]

Helmets and face guards have been effective in facial injury risk reduction by 28 to 69%.[63,64,66] They have shown particular utility in reducing ocular injuries.[67,68] The utilization of headgear in combat sports has shown a significant reduction in soft tissue lacerations. However, use of headgear in noncombat sports such as soccer, and even rugby, has been associated with nonsignificant reductions in injuries.[69–71] As the quality of the literature regarding sports-related CMF trauma and the availability of custom-fitted equipment increases, the resistance toward implementation of these safeguards in everyday practice may decrease. Individuals in combat sports and high-contact sports (football, basketball) or those involving projectiles (baseball, lacrosse) should be encouraged to wear protective gear whenever possible, given their proven utility in such cases.

Postoperative Options

No review in the literature to date has systematically assessed the efficacy, and no broad consensus is in place on the use of postoperative protective equipment following facial trauma repair. If the patient undergoes closed reduction of CMF trauma, the risk of fracture malalignment is higher. Yet, given the low incidence of closed reduction without internal fixation, there is a lack of high-quality data assessing the benefit of protective equipment use following reduction. Furthermore, as the majority of facial fractures are now repaired with open reduction internal fixation, no additional hardware protection is theoretically necessary. Therefore, many of the frequently utilized facial protection equipment postoperatively are being used based on preventative literature, personal preference, and anecdotal evidence currently.

Face Masks/Guards

Face masks and guards following reduction of facial fractures have gained popularity, especially as an increased number of professional athletes are seen in the media with the device (►**Fig. 3A–D**). Farrington et al reviewed that such masks used after facial fracture repair are to prevent reinjury.[49] Custom masks made from polycarbonate blanks over an impression cast of the face can act as a physical guard and can dissipate impact forces to the surrounding tissues and supporting structures. Thus, it is believed that the impact will be lessened and the risk of reinjury decreased after reduction of fracture.[49] However, given the lack of literature, a standardized face mask or guard is not agreed upon. Saraiya reported on the economic use of a window handle taped on the face following closed reduction of isolated zygomatic fractures.[72] Hindin et al reported improved outcomes in the treatment of isolated zygoma fracture with closed reduction followed by transcutaneous external splint application using wires for postoperative protection.[73] However, it is important to note that any protection does not negate the need for proper initial healing and intranasal splinting to prevent hematoma.

External Fixators

Use of external fixators in the treatment of CMF trauma has decreased, but, when insufficient bone is available for proper internal fixation, it provides a good alternative. These injuries may include significant comminution secondary to gunshot wounds or blast injuries, as well as in cases of severe infection associated with the trauma. Given the prominence of the rods, some ingenious ideas have been described and are necessary to decrease the chance of fixator getting caught, snags, or bumped, all leading to mobility of the fixation. In the orthopaedic literature, rings are frequently used to both stabilize and protect the rods, and complete wrapping with bandages may be possible. Although padding of the rods and commercially

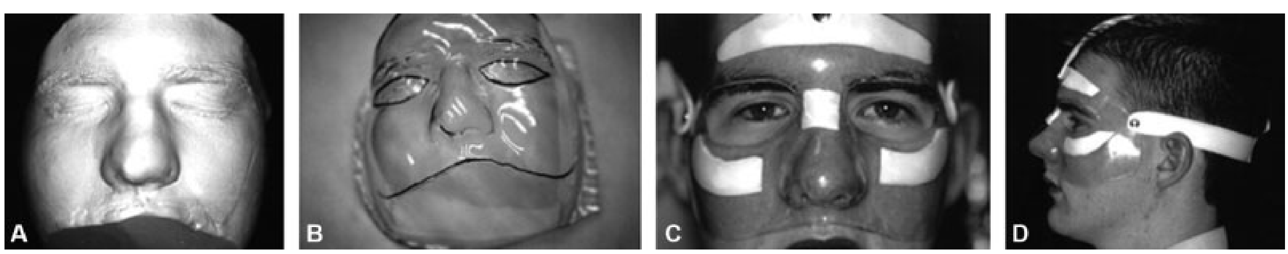

Fig. 3 (A–D) Custom facial shield. (Reproduced with permission of Kaplan S, Driscoll CF, Singer MT. Fabrication of a facial shield to prevent facial injuries during sporting events: a clinical report. J Prosthet Dent 2000;84(4):387–389. doi:10.1067/mpr.2000.109480.)

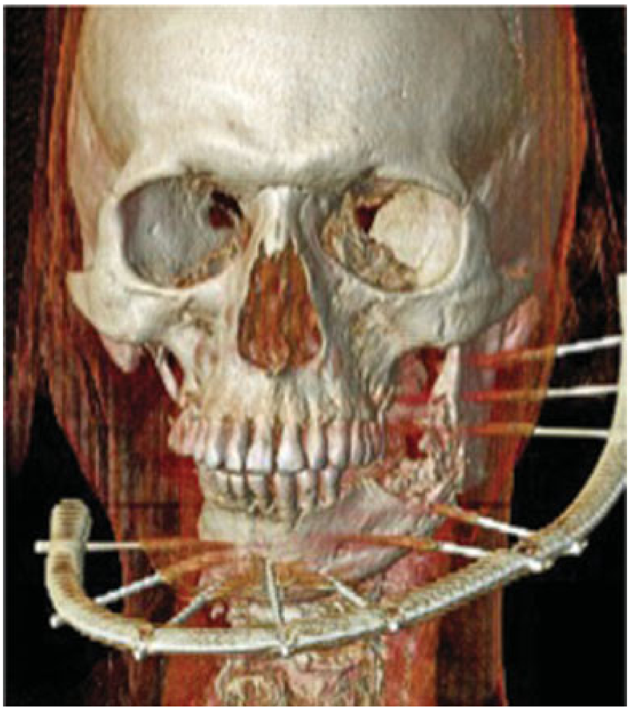

Fig. 4 Economic external fixator custom fabricated using Kirschner pins, endotracheal tube, and dental resin. (Reproduced with permission of Marti-Flich et al[74].)

available cover of the rods are possible, there is yet a customizable commercially available protection for the external fixator. Thermoplastic materials have been utilized to protect the ends of external fixator rods, and a report by Marti-Flich et al has shown an economic custom ex-fix using Kirschner pins, an endotracheal tube, and dental resin (►**Fig. 4**).[74] These improvements may decrease the chance of mobility of the fixator, therefore protecting the healing after CMF trauma.

Splints

Routine use of external splinting occurs following repair of nasal bone fractures. The history of use of thermoplastic or moldable splints is derived from rhinoplasty practice. Taping of the nasal dorsum and splints has been used to decrease postoperative edema and stabilize the nasal bones. There are limited studies, however, assessing the efficacy of such techniques compared with no splinting. The materials and techniques for external splinting are numerous, ranging from polyvinyl siloxane to orthopaedic plates.[75,76] Review of the details of materials and external splinting technique is beyond the scope of this paper. The senior author (Y. D.) routinely uses moldable aluminum splints following closed nasal reduction (►**Fig. 5A–D**). Additionally, if septal work is done, internal support is necessary using Doyle splints. External nasal splinting does carry the risk of applying excess pressure of the soft tissue envelope of the nose and therefore should be avoided should the nasal skin be compromised in any way. The decision to use thermoplastic splints versus preformed titanium or other types of splints therefore depends on surgeon preference.

Occlusal splints for mandible fractures have been largely employed for pediatric mandible fractures.[77] In many cases of nondisplaced mandible fractures with proper occlusion in the pediatric population, simple soft diet is enough to facilitate rapid bony union of the fracture. With significant displacement, and in mixed dentition, reestablishing proper occlusion may be difficult with hand articulation, and postoperative elastic guidance may be necessary. Therefore, utilizing an occlusal splint fabricated on stone models allows precise centric occlusion with the mandible fracture. In the very young pediatric patient who is unable to follow proper instruction, splints may be invaluable to provide reduction of occlusion with temporary maxillomandibular fixation.

Soft Tissue Support

Theoretically, soft tissue support following facial fracture repair, such as after mandible fractures, can help decrease discomfort and perhaps help with edema. In repair of facial fractures, often the approach to the craniofacial skeleton leads to separation of overlying soft tissue from the underlying bone. Efforts should be made to resuspend the soft tissue to the underlying periosteum where possible after internal fixation is complete. No literature is available to support the efficacy of postoperative soft tissue support such as jaw bras and foam tape. Routine use of these is therefore at the discretion of the surgeon. However, patients do note experiencing less edema and general comfort with "protection" of their newly repaired surgical sites.

Cranial Vault Protection

The routine use of helmet protection has been advocated and indeed is standard practice for patients mobilizing after craniectomy in cases where bony flaps are not replaced or

Fig. 5 (A–D) Moldable aluminum splints following closed nasal reduction.

where cranioplasty is not immediately performed. Many complications can occur after cranioplasty, such as infection, increased intracranial pressure, and mucocele.[78] Often, after significant craniofacial trauma, cranioplasty is necessary to reconstruct the deformities incurred along the calvaria. PEEK (polyetheretherketone) implants are frequently used following removal of mesh cranioplasty as long-term custom patient implants. Following definitive cranioplasty, patients do not require postoperative helmet protection. Helmet protection is advocated for cases where part of the calvarium is missing with no rigid barrier for the brain.

Eye Protection

There is no consensus on eye protection following orbital surgery. In general, it is important to limit coverage of the eye to allow for a patient's ongoing assessment of visual changes. Ointment and artificial tears are routine topical treatments postorbital repair. A frost stitch may be necessary to treat conjunctival chemosis and proptosis following severe trauma, as well as to decrease the chances of ectropion. This should be utilized with caution as patients will not be able to note changes in vision in the affected eye and would usually require a clinician to help check the vision and pupillary reflex. Therefore, it should only be considered following exclusion of retrobulbar pathologies.[79] Goggles, face shields, or other eye protection can in theory help prevent reinjury leading to orbital blowout. However, there have been no studies to date assessing the efficacy of postrepair protection. Patients should be counseled on appropriate protective eyewear when engaging in activity that may potentiate ocular injury in general.

Discussions

In this article, we discussed the available preventative options for facial protection, and postoperative considerations to optimize the repair. Although the emphasis was on prevention, we also described many options to improve postoperative healing and stabilization. Lastly, we discuss the challenges, new developments, and potential areas of improvements in CMF trauma protection.

Currently, many efforts are focused on the prevention of injury, stabilization of the repair, prevention of complications, expedited return to function, and decreasing the chance of reinjury. Although we have discussed potential methods of CMF trauma prevention, it is important to note that compliance as well as dissemination of preventative strategies continue to be a challenge. Widespread information in regard to the available of protective materials, such as the mouth guard, is surprisingly low. Dursun et al noted in their study that close to 80% of people were not aware of the benefits of the mouth guard in athletes.[80] Furthermore, awareness of the protective equipment alone provides no benefit; correct compliance in usage of the protection is important. This idea has been described in particular with athletes, as those who do not wear protective equipment actually have higher recurrence rate of injury compared with compliant athletes.[81] Furthermore, in terms of compliance, fit, bulkiness, and retention were also noted to be important. For these reasons, in terms of mouth guards, custom-fabricated mouth guards are recommended.

There are many new and exciting technologies in development and beginning to become commercially available. Many are modifications from previously discovered methods, and improvements based on changes in facial trauma etiology. One such is equipment developed by necessity from combat. During and after the Afghanistan conflict in 2010, in addition to the helmet, Breeze et al showed the utility of mandible guards, protective goggles, and visors in improving facial protections for the soldiers (►**Fig. 6A–D**). Especially in regard to explosive fragments, the amount of protection given by a combination of mandible guard and visor was superior.[82] Perhaps, given the protection again explosive fragments, these technologies can be adapted to occupational protection, as we described for welders and construction workers.

Also, given that innovation and technologies are produced faster than ever before, there are improvements and amalgamation of protective equipment already in place. One such development includes the expandable helmets. Hovding airbag (Hovding, Malmo, Sweden), described as the "airbag for cyclist," combines the protection of a bicycle helmet with an impact deployed airbag. It provides circumferential protection of the head and neck region. However, no independent data exist for its safety and efficacy, and like the helmet, there is no specific protection given for the eyes or the maxillofacial structures. On theoretical models and anthropomorphic test dummy experiments, compared with traditional foam helmets, these "expandable helmets" have shown to substantially decreased risks of severe head injury up to 9 m/s.[83]

Lastly, three-dimensional (3D) printing has become widely available and is becoming much more affordable. With innovative strategies utilizing optical scanning of soft tissue, there are more and more customization and applications for 3D printed materials. Therefore, 3D-printed custom protective equipment have become readily available. Although many are for the current pandemic, it is exciting to foresee the potential 3D printing technology may have for customized facial protection in both pre- and postoperative settings.

Fig. 6 (A–D) Mandible guards, protective goggles, visor, and helmet developed by the military. (Reproduced with permission of Breeze et al[82].)

Conclusions

Facial skeletal trauma continues to be a frequent clinical problem for the CMF surgeons. In addition to a sound understanding of the surgical interventions, preventative as well as postoperative protection allows optimal care for the patients. Further understanding and utilization of prevention and postoperative protection may lead to decreased morbidity and mortality.

Conflict of Interest
None declared.

References

1 Ribeiro Ribeiro AL, da Silva Gillet LC, de Vasconcelos HG, de Castro Rodrigues L, de Jesus Viana Pinheiro J, de Melo Alves-Junior S. Facial fractures: large epidemiologic survey in Northern Brazil reveals some unique characteristics. J Oral Maxillofac Surg 2016; 74(12):2480.e1–2480.e12
2 Gaddipati R, Ramisetti S, Vura N, Reddy KR, Nalamolu B. Analysis of 1,545 fractures of facial region-a retrospective study. Craniomaxillofac Trauma Reconstr 2015;8(04):307–314
3 Haug RH, Prather J, Indresano AT. An epidemiologic survey of facial fractures and concomitant injuries. J Oral Maxillofac Surg 1990;48(09):926–932
4 Cornelius CP, Gellrich N, Hillerup S, Kusumoto K, Schubert W. AO Surgery Reference. Available at: https://surgeryreference.aofoundation.org/cmf/trauma/midface/further-reading/introduction. Accessed May 10, 2020
5 Frommer SA, Bhatt RA. Sports-Related Facial Trauma. Accessed May 19, 2020 at: https://emedicine.medscape.com/article/1284288-overview#showall
6 Roccia F, Dell'Acqua A, Angelini G, Berrone S. Maxillofacial trauma and psychiatric sequelae: post-traumatic stress disorder. J Craniofac Surg 2005;16(03):355–360
7 Hull AM, Lowe T, Devlin M, Finlay P, Koppel D, Stewart AM. Psychological consequences of maxillofacial trauma: a preliminary study. Br J Oral Maxillofac Surg 2003;41(05):317–322
8 Levine E, Degutis L, Pruzinsky T, Shin J, Persing JA. Quality of life and facial trauma: psychological and body image effects. Ann Plast Surg 2005;54(05):502–510
9 Sahni V. Psychological impact of facial trauma. Craniomaxillofac Trauma Reconstr 2018;11(01):15–20
10 Moses H, Powers D, Keeler J, et al. Opportunity cost of surgical management of craniomaxillofacial trauma. Craniomaxillofac Trauma Reconstr 2016;9(01):76–81
11 Goulart DR, Durante L, de Moraes M, Asprino L. Characteristics of maxillofacial trauma among alcohol and drug users. J Craniofac Surg 2015;26(08):e783–e786
12 Othman S, Cohn JE, Toscano M, Shokri T, Zwillenberg S. Substance use and maxillofacial trauma: a comprehensive patient profile. J Oral Maxillofac Surg 2020;78(02):235–240
13 Smith AJ, Hodgson RJ, Bridgeman K, Shepherd JP. A randomized controlled trial of a brief intervention after alcohol-related facial injury. Addiction 2003;98(01):43–52
14 Eggensperger NM, Danz J, Heinz Z, Iizuka T. Occupational maxillofacial fractures: a 3-year survey in central Switzerland. J Oral Maxillofac Surg 2006;64(02):270–276
15 Yamamoto K, Matsusue Y, Murakami K, et al. Maxillofacial fractures due to work-related accidents. J Craniomaxillofac Surg 2011;39(03):182–186
16 Girotto JA, MacKenzie E, Fowler C, Redett R, Robertson B, Manson PN. Long-term physical impairment and functional outcomes after complex facial fractures. Plast Reconstr Surg 2001;108 (02):312–327
17 Janicak CA. An examination of occupational fatalities involving impact-related head injuries in the construction industry. J Occup Environ Med 1998;40(04):347–350
18 Konda S, Reichard A, Tiesman HM, Hendricks S. Non-fatal work-related traumatic brain injuries treated in US hospital emergency departments, 1998-2007. Inj Prev 2015;21(02):115–120
19 Iizuka T, Randell T, Güven O, Lindquist C. Maxillofacial fractures related to work accidents. J Craniomaxillofac Surg 1990;18(06): 255–259
20 Hächl O, Tuli T, Schwabegger A, Gassner R. Maxillofacial trauma due to work-related accidents. Int J Oral Maxillofac Surg 2002;31 (01):90–93
21 Exadaktylos AK, Bournakas T, Eggli S, Zimmermann H, Iizuka T. Maxillofacial injuries related to work accidents: a new concept of a hospital-based full electronic occupational trauma surveillance system. Occup Med (Lond) 2002;52(01):45–48
22 Dang S. Eye injuries at work. Am Academy Ophthalmology 2016. Available at: http://www.aao.org/eye-health/tips-prevention/injurieswork. Accessed May 16, 2020
23 Lipscomb HJ, Dement JM, McDougall V, Kalat J. Work-related eye injuries among union carpenters. Appl Occup Environ Hyg 1999; 14(10):665–676
24 Welch LS, Hunting KL, Mawudeku A. Injury surveillance in construction: eye injuries. Appl Occup Environ Hyg 2001;16 (07):755–762
25 Lombardi DA, Pannala R, Sorock GS, et al. Welding related occupational eye injuries: a narrative analysis. Inj Prev 2005;11 (03):174–179
26 Reesal MR, Dufresne RM, Suggett D, Alleyne BC. Welder eye injuries. J Occup Med 1989;31(12):1003–1006
27 Yu TS, Liu H, Hui K. A case-control study of eye injuries in the workplace in Hong Kong. Ophthalmology 2004;111(01):70–74
28 Lipscomb HJ. Effectiveness of interventions to prevent work-related eye injuries. Am J Prev Med 2000;18(4, Suppl):27–32
29 Weeks J, Levy B, Wagner G, Eds. Preventing Occupational Disease and Injury. Washington, DC: American Public Health Association; 1991:245–249
30 Zakrzewski H, Chung H, Sanders E, Hanson C, Ford B. Evaluation of occupational ocular trauma: are we doing enough to promote eye safety in the workplace? Can J Ophthalmol 2017;52(04):338–342
31 Hoskin AK, Mackey DA, Keay L, Agrawal R, Watson S. Eye Injuries across history and the evolution of eye protection. Acta Ophthalmol 2019;97(06):637–643
32 Leonard JC. National trends in ocular injury: differing studies, common call to action. JAMA Ophthalmol 2019;137(01):56–57
33 Nakhgevany KB, LiBassi M, Esposito B. Facial trauma in motor vehicle accidents: etiological factors. Am J Emerg Med 1994;12 (02):160–163
34 Stacey DH, Doyle JF, Gutowski KA. Safety device use affects the incidence patterns of facial trauma in motor vehicle collisions: an analysis of the National Trauma Database from 2000 to 2004. Plast Reconstr Surg 2008;121(06):2057–2064
35 Major MS, MacGregor A, Bumpous JM. Patterns of maxillofacial injuries as a function of automobile restraint use. Laryngoscope 2000;110(04):608–611
36 Simoni P, Ostendorf R, Cox AJ III. Effect of air bags and restraining devices on the pattern of facial fractures in motor vehicle crashes. Arch Facial Plast Surg 2003;5(01):113–115
37 Roccia F, Servadio F, Gerbino G. Maxillofacial fractures following airbag deployment. J Craniomaxillofac Surg 1999;27(06):335–338
38 McGwin G Jr, Metzger J, Alonso JE, Rue LW III. The association between occupant restraint systems and risk of injury in frontal motor vehicle collisions. J Trauma 2003;54(06):1182–1187
39 Mouzakes J, Koltai PJ, Kuhar S, Bernstein DS, Wing P, Salsberg E. The impact of airbags and seat belts on the incidence and severity of maxillofacial injuries in automobile accidents in New York State. Arch Otolaryngol Head Neck Surg 2001;127(10):1189–1193

40 Murphy RX Jr, Birmingham KL, Okunski WJ, Wasser T. The influence of airbag and restraining devices on the patterns of facial trauma in motor vehicle collisions. Plast Reconstr Surg 2000;105(02):516–520
41 Kent RW, Crandall JR, Bolton JR, Duma SM. Driver and right-front passenger restraint system interaction, injury potential, and thoracic injury prediction. Annu Proc Assoc Adv Automot Med 2000;44:261–282
42 Huff GF, Bagwell SP, Bachman D. Airbag injuries in infants and children: a case report and review of the literature. Pediatrics 1998;102(01):e2
43 Charyk Stewart T, McClafferty K, Shkrum M, Comeau JL, Gilliland J, Fraser DD. A comparison of injuries, crashes, and outcomes for pediatric rear occupants in traffic motor vehicle collisions. J Trauma Acute Care Surg 2013;74(02):628–633
44 Dreyfus J, Flood A, Cutler G, Ortega H, Kreykes N, Kharbanda A. Comparison of pediatric motor vehicle collision injury outcomes at Level I trauma centers. J Pediatr Surg 2016;51(10):1693–1699
45 Findlay BL, Melucci A, Dombrovskiy V, Pierre J, Lee YH. Children after motor vehicle crashes: restraint utilization and injury severity. J Pediatr Surg 2019;54(07):1411–1415
46 Glerum KM, Zonfrillo MR, Fleisher L, McDonald CC. Systematic review of child restraint system interventions (2007-2018). Traffic Inj Prev 2019;20(08):866–872
47 Bulger EM, Kaufman R, Mock C. Childhood crash injury patterns associated with restraint misuse: implications for field triage. Prehosp Disaster Med 2008;23(01):9–15
48 Berg MD, Cook L, Corneli HM, Vernon DD, Dean JM. Effect of seating position and restraint use on injuries to children in motor vehicle crashes. Pediatrics 2000;105(4 Pt 1):831–835
49 Farrington T, Onambele-Pearson G, Taylor RL, Earl P, Winwood K. A review of facial protective equipment use in sport and the impact on injury incidence. Br J Oral Maxillofac Surg 2012;50(03):233–238
50 Hawn KL, Visser MF, Sexton PJ. Enforcement of mouthguard use and athlete compliance in National Collegiate Athletic Association men's collegiate ice hockey competition. J Athl Train 2002;37(02):204–208
51 Labella CR, Smith BW, Sigurdsson A. Effect of mouthguards on dental injuries and concussions in college basketball. Med Sci Sports Exerc 2002;34(01):41–44
52 Cohenca N, Roges RA, Roges R. The incidence and severity of dental trauma in intercollegiate athletes. J Am Dent Assoc 2007;138(08):1121–1126
53 Quarrie KL, Gianotti SM, Chalmers DJ, Hopkins WG. An evaluation of mouthguard requirements and dental injuries in New Zealand rugby union. Br J Sports Med 2005;39(09):650–651
54 Tanaka Y, Maeda Y, Yang TC, Ando T, Tauchi Y, Miyanaga H. Prevention of orofacial injury via the use of mouthguards among young male rugby players. Int J Sports Med 2015;36(03):254–261
55 Duarte-Pereira DMV, Del Rey-Santamaria M, Javierre-Garcés C, et al. Wearability and physiological effects of custom-fitted vs self-adapted mouthguards. Dent Traumatol 2008;24(04):439–442
56 Queiróz AFVR, de Brito RB Jr, Ramacciato JC, Motta RH, Flório FM. Influence of mouthguards on the physical performance of soccer players. Dent Traumatol 2013;29(06):450–454
57 Finch C, Braham R, McIntosh A, McCrory P, Wolfe R. Should football players wear custom fitted mouthguards? Results from a group randomised controlled trial. Inj Prev 2005;11(04):242–246
58 Danis RP, Hu K, Bell M. Acceptability of baseball face guards and reduction of oculofacial injury in receptive youth league players. Inj Prev 2000;6(03):232–234
59 Marshall SW, Mueller FO, Kirby DP, Yang J. Evaluation of safety balls and faceguards for prevention of injuries in youth baseball. JAMA 2003;289(05):568–574
60 Khan MI, Flynn T, O'Connell E, Stack J, Beatty S. The impact of new regulations on the incidence and severity of ocular injury sustained in hurling. Eye (Lond) 2008;22(04):475–478
61 Benson BW, Mohtadi NG, Rose MS, Meeuwisse WH. Head and neck injuries among ice hockey players wearing full face shields vs half face shields. JAMA 1999;282(24):2328–2332
62 National Operating Committee on Standards for Athletic Equipment. Standard Method of Impact Test and Performance Requirements for Football Faceguards. Overland Park, KS: National Operating Committee on Standards for Athletic Equipment; 2015
63 American Society for Testing and Materials. Standard Specification for Head and face Protective Equipment for Ice Hockey Goaltenders ASTM F1587. West Conshohocken, PA: American Society for Testing and Materials; 2012
64 National Operating Committee on Standards for Athletic Equipment. Standard Performance Specification for Newly Manufactured Baseball/Softball Batter's Helmet Mounted Face Protector. Overland Park, KS: National Operating Committee on Standards for Athletic Equipment; 2013
65 National Operating Committee on Standards for Athletic Equipment. Standard Performance Specification for Newly Manufactured Lacrosse Helmets with Faceguard. Overland Park, KS: National Operating Committee on Standards for Athletic Equipment; 2012
66 LaPrade RF, Burnett QM, Zarzour R, Moss R. The effect of the mandatory use of face masks on facial lacerations and head and neck injuries in ice hockey. A prospective study. Am J Sports Med 1995;23(06):773–775
67 Stuart MJ, Smith AM, Malo-Ortiguera SA, Fischer TL, Larson DR. A comparison of facial protection and the incidence of head, neck, and facial injuries in Junior A hockey players. A function of individual playing time. Am J Sports Med 2002;30(01):39–44
68 Stevens ST, Lassonde M, de Beaumont L, Keenan JP. The effect of visors on head and facial injury in National Hockey League players. J Sci Med Sport 2006;9(03):238–242
69 Jones SJ, Lyons RA, Evans R, et al. Effectiveness of rugby headgear in preventing soft tissue injuries to the head: a case-control and video cohort study. Br J Sports Med 2004;38(02):159–162
70 Zazryn TR, McCrory PR, Cameron PA. Injury rates and risk factors in competitive professional boxing. Clin J Sport Med 2009;19(01):20–25
71 Delaney JS, Al-Kashmiri A, Drummond R, Correa JA. The effect of protective headgear on head injuries and concussions in adolescent football (soccer) players. Br J Sports Med 2008;42(02):110–115, discussion 115
72 Saraiya H. Use of a window handle for postreduction protection of a fractured zygoma. Plast Reconstr Surg 2006;117(01):331–332
73 Hindin DI, Muetterties CE, Mehta C, Boukovalas S, Lee JC, Bradley JP. Treatment of isolated zygomatic arch fracture: improved outcomes with external splinting. Plast Reconstr Surg 2017;139(05):1162e–1171e
74 Marti-Flich L, Schlund M, Raoul G, et al. Twenty-four years of experience in management of complex mandibular fractures with low cost, custom-made mandibular external fixation: a 65-patient series. J Stomatol Oral Maxillofac Surg 2020;121(03):242–247
75 Jayakumar NK, Rathnaprabhu V, Ramesh S, Parameswaran A. Polyvinyl siloxane: novel material for external nasal splinting. Int J Oral Maxillofac Surg 2016;45(01):57–59
76 Kochar HS. An innovative approach to external fixation of severe nasal bone fractures with orthopedic plates. Ear Nose Throat J 2011;90(03):102–104
77 Nezam S, Kumar A, Shukla JN, Khan SA. Management of mandibular fracture in pediatric patient. Natl J Maxillofac Surg 2018;9(01):106–109
78 Kato A, Morishima H, Nagashima G. Unexpected complications immediately after cranioplasty. Acute Med Surg 2017;4(03):316–321

79 Krishnan R, Izadi S, Morton CE, Marsh IB. Use of Frost sutures in an orbital trauma patient with extensive conjunctival oedema and pseudoproptosis. Int J Oral Maxillofac Surg 2007;36(07):649–651
80 Dursun E, Ilarslan YD, Ozgul O, Donmez G. Prevalence of dental trauma and mouthguard awareness among weekend warrior soccer players. J Oral Sci 2015;57(03):191–194
81 Ellis TH. Sports protective equipment. Prim Care 1991;18(04):889–921
82 Breeze J, Allanson-Bailey LC, Hepper AE, Lewis EA. Novel method for comparing coverage by future methods of ballistic facial protection. Br J Oral Maxillofac Surg 2015;53(01):3–7
83 Kurt M, Laksari K, Kuo C, Grant GA, Camarillo DB. Modeling and optimization of airbag helmets for preventing head injuries in bicycling. Ann Biomed Eng 2017;45(04):1148–1160

